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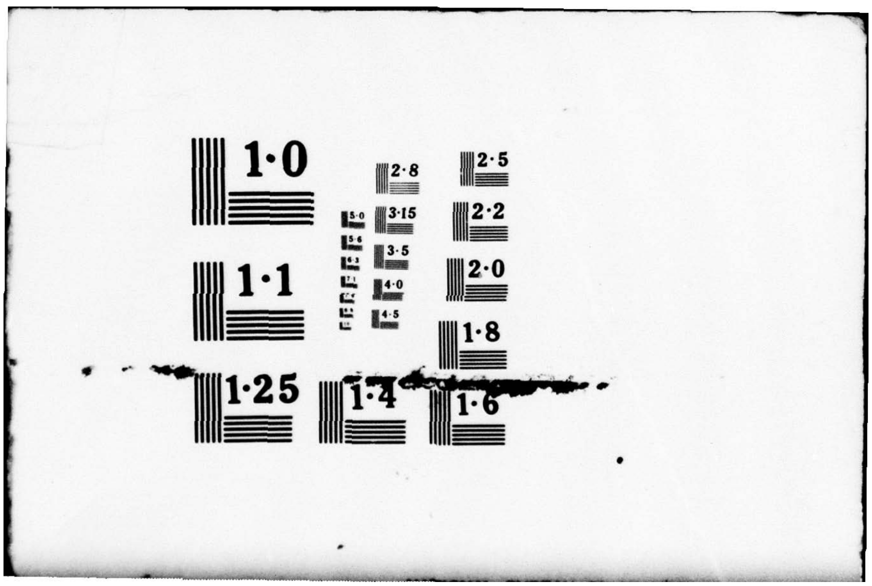

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FINAL REPORT, 1 Apr 77 - 31 Mar 78,

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SENSITIVITY OF NOISEMAP CONTOURS TO CHANGES IN AIRCRAFT OPERATIONS.

15 ✓AFOSR-77-3308

10 David K. Holger
Principal Investigator

Submitted to the
U. S. Air Force Office
of Scientific Research
Grant No. 77-3308

11 May 1978

12 31p.

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Project 1283

DEPARTMENT OF ENGINEERING SCIENCE AND MECHANICS
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFOSR-TR- 78-1062	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SENSITIVITY OF NOISEMAP CONTOURS TO CHANGES IN AIRCRAFT OPERATIONS		5. TYPE OF REPORT & PERIOD COVERED FINAL 1 Apr 77 - 31 Mar 78
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) DAVID K HOLGER		8. CONTRACT OR GRANT NUMBER(s) AFOSR 77-3308 new
9. PERFORMING ORGANIZATION NAME AND ADDRESS IOWA STATE UNIVERSITY ENGINEERING RESEARCH INSTITUTE AMES, IOWA 50011		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2307D2 61102F
11. CONTROLLING OFFICE NAME AND ADDRESS AIR FORCE OFFICE OF SCIENTIFIC RESEARCH/NA BLDG 410 BOLLING AIR FORCE BASE, D C 20332		12. REPORT DATE May 1978
		13. NUMBER OF PAGES 20
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION ST. ENT (of ... abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY TES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

NOISEMAP
NOISE
AIRPORT NOISE

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Sets of numerically generated noise exposure contours are available for the vicinity of most domestic Air Force bases and many civilian airports. For such bases, a simple method for manually predicting the change in area enclosed by a given noise exposure contour is described. Such predictions are used for determining whether or not a full scale computer rerun is necessary for a given set of operational changes. The method proposed involves first estimating the change in contour value for a given point and then using that change in contour value to estimate the change in area enclosed by a given contour. The results of

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several full scale computer runs using the USAF NOISEMAP computer program to test the proposed method are presented.

FINAL SCIENTIFIC REPORT

USAFOSR GRANT 77-3308

Title:	SENSITIVITY OF NOISEMAP CONTOURS TO CHANGES IN AIRCRAFT OPERATIONS
Principal Investigator:	David K. Holger, Assistant Professor SS #: 476-58-2958 Department of Engineering Science and Mechanics Engineering Research Institute
Institution:	Iowa State University Ames, Iowa 50011
Period Funded:	4-1-77 to 3-31-78
Total Grant:	$10,000

ISU-ERI-Ames-78292
Project 1283

INTRODUCTION

The volume of actual or potential changes in aircraft operations at United States Air Force Bases is large enough to make it impossible to use the NOISEMAP computer program to generate new sets of noise exposure contours for all cases. However, environmental considerations require that all proposed operational changes be evaluated for their potential noise impact. Sets of numerically generated noise exposure contours are available for the vicinity of most domestic Air Force bases. The primary thrust of the research funded by this grant was to investigate ways to use existing contours to predict noise impact of operational changes. The predicted noise impact may then be used as a criterion for determining whether or not full scale computer studies using the NOISEMAP computer program are necessary. This report suggests possible improvements to the screening procedure currently in use.

SUMMARY OF RESULTS

The research supported by this grant is described in a paper to be presented at the Acoustical Society of America meeting in May 1978 [1].* Copies of the paper are enclosed and only the results of the research will be summarized in this report. The following results were obtained in the course of the research.

1. The present screening procedure's method for computing a "partial" DNL [2] or some similar method for predicting the total expected change in DNL at a base is a good approximation. In order to make quantitative estimates of the change in area enclosed by a given contour an estimate of the total change in DNL at a point is a necessary first step.
2. The percentage change in area enclosed by a contour due to an N-dB increase in contour value is equal to the percentage change in area enclosed by a given contour if the DNL value at a point increases by N-dB.
3. The currently used relationship that

   $$DNL = a - 15 \log (\text{contour area})$$

   is approximately valid for all bases studied.
4. The prediction from result number three above that the fractional enclosed area change is equal to $10^{\Delta L/15} - 1$ was verified as shown in Fig. 1 of reference [1].
5. Full scale NOISEMAP studies indicate that changes in area

*Numbers in brackets refer to references at the end of this report.

enclosed by contours caused by operational changes may be estimated by first estimating the total change in DNL at a point due to operational changes and then using result number four above.

6. The above results, which are discussed in [1], indicate that quantitative estimates for changes in area enclosed by a DNL contour may be obtained in a simple way from data about operational changes and current enclosed areas.

SCREENING PROCEDURE BASED ON CHANGE IN ENCLOSED AREA

The above results may be used to develop a revised method for screening air bases which are candidates for full scale NOISEMAP reruns. The procedure described gives an estimate of the change in area enclosed by a contour and hence allows an estimate of the noise impacted population if population densities near a base are known. It has the disadvantage that an estimate for the total change in DNL at a point must be available. Only further study will reveal whether or not such a single number estimate for a base is simply obtainable and accurate. The procedure also is limited to cases where major changes in base mission or layout do not occur. An outline of a possible screening method based on enclosed area is as follows.

Step 1: Identify proposed changes in air base operations as is done currently [2].

Step 2: Determine average takeoffs, landings and ground run-ups for day (0700 to 2200) and night (2200 - 0700) periods for each aircraft type before and after the proposed change.

Step 3: Calculate partial DNL values for each aircraft type in a manner similar to that of [2], but include all operations rather than takeoffs alone as is currently done.

Step 4: Calculate total LDN's before and after the operational change under consideration. The difference between the two values is an estimate of the change in contour value at a point.

Step 5: Estimate the change in area enclosed by a contour from

$$\frac{\Delta A}{A} = 10^{\Delta LDN/15} - 1$$

Step 6: Evaluate the impact of that fractional change in area by looking at the population density around the air base. Under this scheme the present 1 dB DNL change would correspond to a change in area of 17%.

PUBLICATIONS

1. "Predicting Changes in Area Exposed to Aircraft Noise," to be presented at the 95th meeting of the Acoustical Society of America, May 16-19, 1978 in Providence, Rhode Island.

2. A revised version of the above paper will be submitted to Noise Control Engineering later in 1978.

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1. D. K. Holger, "Predicting Changes in Area Exposed to Aircraft Noise," to be presented at the 95th meeting of the Acoustical Society of America, May 16-19, 1978 in Providence, Rhode Island.

2. D. E. Bishop, "A Suggested Method for Screening the Impact of Air Force/Air Base Changes on Day/Night Level Contours," Tech. Memo. to USAF/PREVX, Oct. 1976.

ERI - 78291
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PREDICTING CHANGES IN AREA EXPOSED TO AIRCRAFT NOISE

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May 1978

This paper was prepared for submission to the 95th Meeting of the Acoustical Society of America, May 16-19, 1978, Providence, RI

ABSTRACT

Sets of numerically generated noise exposure contours are available for the vicinity of most domestic Air Force bases and many civilian airports. For such bases, a simple method for manually predicting the change in area enclosed by a given noise exposure contour is described. Such predictions are used for determining whether or not a full scale computer rerun is necessary for a given set of operational changes. The method proposed involves first estimating the change in contour value for a given point and then using that change in contour value to estimate the change in area enclosed by a given contour. The results of several full scale computer runs using the USAF NOISEMAP computer program to test the proposed method are presented. (Work supported by the Engineering Research Institute of Iowa State University through a grant from the United States Air Force Office of Scientific Research.)

Technical Committee: Noise

Subject Classification Number(s): 43.50.Lj

INTRODUCTION

There are many situations involving aircraft noise in which it would be useful to have a relatively simple model relating area enclosed by a given noise exposure contour to the value of that contour and possibly some other parameters involving operations and types of aircraft. Extensive studies of such models have been carried out for civilian airport operations. These studies have resulted in models capable of estimating changes in contour areas caused by changes in aircraft operational procedures, volume of operation, type and mix [1].* A typical model resulting from such studies is

$$A = A_o \, 10^{\frac{10 \log N_e - NEF + C}{15}} \tag{1}$$

which is used by the Civil Aeronautics Board to screen the environmental noise impact of airline schedule changes. In Eq. (1), A_o is a constant related to fleet mix and NEF contour value, NEF is the Noise Exposure Forecast contour value, N_e is the effective number of operations and C is an adjustment for the mix between day and night operations, fleet mix and trip length.

Attempts to obtain a relationship such as given in Eq. (1) for Air Force bases have been unsuccessful. Correlations between models such as Eq. (1) and numerically obtained enclosed areas for actual base situations are poor. Even bases with similar missions and aircraft are often modeled poorly by Eq. (1) or similar simple relationships [2]. The reasons for the poor correlation between the results

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*Numbers in brackets refer to references at the end of this paper.

of civilian models such as Eq. (1) and the actual contours at Air Force bases is unclear. For the purposes of this paper the important fact is that models of the type described by Eq. (1) are not adequate for the prediction of the contour value for a given enclosed area.

For most domestic Air Force bases a set of noise exposure contours for current operations is in existence. The contours generally consist of contour maps and enclosed area estimates for 65, 70, 75, 80, and 85 dB day/night equivalent level (LDN) contours. The contours are generated numerically using the USAF NOISEMAP computer program [3-8]. The program predictions have been experimentally verified to be within 1 to 2 dB for at least one case [9].

While the NOISEMAP computer program is accurate, it is expensive and time consuming to run. The volume of actual and potential changes in operations, aircraft type or mix, or mission for Air Force bases is large enough to make it impossible to recalculate contours using NOISEMAP for all cases. However, environmental considerations require that all proposed changes be evaluated for potential alterations they may cause in the noise environment. The USAF through contractors is currently working on screening procedures aimed at identifying which changes at base level will require new contours to be generated using NOISEMAP.

CHANGE IN CONTOUR VALUE AT A POINT

The current method for screening bases which are candidates for NOISEMAP reruns involves estimating the expected day/night sound level

(LDN) changes at a point for various groups of aircraft at the base [10]. The changes are estimated by calculating "partial" LDN values for each aircraft type from

$$L_p = S_p + 10 \log [N_D + 10 N_N] - 49.4 \qquad (2)$$

In Eq. (2), L_p is the "partial" LDN, S_p is a sound exposure level (SEL) under similar conditions for each aircraft type, N_D is the number of day takeoffs, and N_N is the number of night takeoffs. These L_p are then combined for aircraft types in each of four groups to give four group L_p. The change in these group L_p is then calculated by taking the difference between group L_p before and after the proposed operational modifications. If the changes in group L_p are less than a prescribed value, the potential changes in the noise environment are considered to be unimportant and full scale NOISEMAP reruns are not made.

The present screening procedure suggests a simple means for obtaining a quantitative estimate of the change in LDN value at a given point due to operational changes at a base. By combining the group L_p for all operations one can easily obtain an estimate for the total change in LDN at a point. Once an estimate for the change in LDN is obtained, it is desirable to use that estimate to obtain information about the increase in enclosed area to be expected for a given (fixed) contour value. This paper will use the above method for estimating changes in contour value at a point together with relationships obtained in the course of this work between enclosed area change and contour value change to investigate the relationship between operational changes and enclosed area changes.

RELATIONSHIP BETWEEN AREA AND CONTOUR VALUE

It has been found [2] that for a given military air base an adequate relationship between enclosed area and LDN value is

$$LDN = B - 15 \log (A) \qquad (3)$$

Here, B is a constant for a given base and set of operations, and A is the area enclosed by a contour of value LDN. By using Eqs. (2) and (3) it is possible to obtain the desired relationship between change in the enclosed area and change in operations.

For the change in area enclosed by a <u>contour of fixed value</u> caused by a change in operations, Eq. (3) gives

$$15 \log \left(\frac{A_2}{A_1}\right) = B_2 - B_1 \qquad (4)$$

where the subscripts 1 and 2 denote values before and after the change, respectively. Using Eq. (3) to estimate the contour value change caused by a change in operations, if the enclosed <u>area is held fixed</u>, gives

$$(LDN)_2 - (LDN_1) = B_2 - B_1 \qquad (5)$$

Since, for a given base, B_2 and B_1 depend only on operations at the base, Eq. (5) determines the value of $(B_2 - B_1)$. This value is thus equal to the right hand side of Eq. (4) even though for Eq. (4) the enclosed area is not fixed. Therefore

$$15 \log \left(\frac{A_2}{A_1}\right) = (LDN)_2 - (LDN)_1 \qquad (6)$$

relates the expected change in LDN contour value at a point to the

change in area enclosed by a contour of fixed value in the vicinity of that point.

By using Eq. (2) and methods similar to those described in the previous section to estimate $(LDN)_2 - (LDN)_1$ at a point, it is possible to obtain from Eq. (6) an estimate for the change in area enclosed by a contour. The result is that

$$\frac{A_2 - A_1}{A_1} = 10^{\Delta L/15} - 1 \tag{7}$$

where $\Delta L = (LDN)_2 - (LDN)_1$. The following sections of this work will investigate the validity of Eqs. (6) and (7) by reporting the results of full scale NOISEMAP simulations for several military bases.

NOISEMAP SIMULATIONS

The NOISEMAP computer program uses actual operational data for a given base and measured noise data for each aircraft in the inventory to predict noise exposure contours near the base. NOISEMAP runs for actual bases were examined in order to study the change in area enclosed by a given LDN contour caused by a change in base operations. All computer runs made in the course of the study include all aircraft operations at an installation in exactly the same way they they would be included for a production run of NOISEMAP. As a result, computer runs could only be carried out for a limited number of bases because of time as well as economic constraints.

On the basis of operational statistics and aircraft types seven representative military air bases were chosen for detailed analysis.

For each of the seven bases the enclosed area for contour values (LDN) from 60 to 90 dB was computed by 1 dB increments. The resulting areas (31 per base) were used to check the validity of Eq. (3) and to compute the fractional change in enclosed area caused by an n-dB contour value increase for n = 1, 2, 3, 4, and 5. The fractional area changes were computed for each base using the relationship

$$D_{Ki} = \frac{A(LDN_i) - A(LDN_{i+K})}{A(LDN_{i+K})} \tag{8}$$

where D_{Ki} is the fractional area change for a K-dB contour value increase of the i-th contour. Thus, for each of the seven bases there are 30 values of D_{Ki} for K = 1, 29 values for K = 2 and so on.

For each base the values of D_{Ki} were averaged over i for K = 1 to 5. Also, for fixed i and K, the D_{Ki} were averaged over the seven bases. For both averages a standard deviation was computed. Both averages were computed to allow a check of result correlations within a base and at a fixed contour value. In an attempt to increase the sample size, existing data for 40 bases for which enclosed areas for the LDN contour values of 65, 70, 75, 80, 85 were available were also analyzed. The inter- and intra-base averages were again computed for D_{Ki} with K fixed at 5.

In addition, numerous computer runs were made for various operational changes at several of the bases. Equation (2) was used to obtain an estimate for ΔL and the results of the full scale runs could then be used to check the validity of Eq. (7). This amounts to an overall validity test for the combined result of Eqs. (2) and (3).

One particular type of operational change was investigated in

some detail because of its simplicity. This change was the constant fractional increase or decrease of all operations at a base. For this case, Eq. (2) gives

$$\Delta L = 10 \log \alpha \tag{9}$$

where $(N_D)_2 = \alpha(N_D)_1$ and $(N_N)_2 = \alpha\ (N_N)_1$. When substituted in Eq. (7), Eq. (9) gives the result

$$\frac{A_2 - A_1}{A_1} = \alpha^{2/3} - 1 \tag{10}$$

Because this type of operational change is convenient to simulate computationally, extensive studies of the validity of Eq. (10) were made. Less extensive studies were made of other types of operational changes by using Eq. (2) to directly estimate ΔL.

RESULTS

The data at 1 dB increments for enclosed area vs. contour value at seven bases were used to obtain a nonlinear least squares fit to an equation of the form

$$LDN = C_1 - C_2 \log (A)$$

for each base. The resulting "best fit" values for C_1 and C_2 are tabulated in Table I. Results for several different operational conditions for one base, although not included, indicated that C_1 was nearly constant for a given base. Equation (3) indicates that C_2 should be approximately 15 for all bases and this is seen to be roughly

Table I. Least squares coefficients, C_1 and C_2 for LDN = C_1 - C_2 log (A).

Base	C_1	C_2
Cannon	89.8	17.2
Fairchild	107.0	19.2
Kelly	81.3	15.2
Macdill	89.5	16.0
McChord	83.7	14.8
Myrtle Beach	95.3	16.3
Randolph	85.0	14.4
MEAN	90.2	16.2
STD. DEV.	8.7	1.6

roughly the case. The mean of the seven C_2 values is 16.2, which is within a standard deviation of the expected value of 15.

The results obtained for the seven bases in terms of percentage enclosed area change due to change in contour value are summarized in Tables II and III. Table II contains results obtained by averaging D_{Ki} over i (all contours at a base) with K (change in contour value) fixed. Also included are averages over the seven bases of these averaged values, $\bar{D}_K$, where

$$\bar{D}_K = \frac{\sum_{i=1}^{31-K} D_{Ki}}{31-K} , \tag{11}$$

standard deviations and the areas enclosed by the 60 and 80 dB contours. The fact that the standard deviations of the inter-base averages are significantly less than the average intra-base standard deviations suggests that a single value

$$D(K) \equiv \frac{\sum_{i=1}^{7} (\bar{D}_K)_j}{7}$$

is probably a good characterization for the fractional area change caused by a K-dB contour value increase.

Table III contains data obtained by averaging D_{Ki} over seven bases while holding K fixed at one for LDN_i equal to 60, 65, 70, 75, 80, and 85 dB. The table illustrates that the standard deviation for a base average with both contour value and change in contour value held fixed are comparable to those obtained in intra-base averages over i. It is possible that if the correlation were done for K fixed and area fixed and averaged over the bases that a better

Table II. Fractional changes in enclosed areas for 1,2,3, and 4 dB changes in contour value averaged for all contour values from LDN 60 to 90 dB.

Base	1 dB		2 dB		3 dB		4 dB		Sq. Miles	
	$\bar{D}_k$	$\sigma\bar{D}_k$	$\bar{D}_k$	$\sigma\bar{D}_k$	$\bar{D}_k$	$\sigma\bar{D}_k$	$\bar{D}_k$	$\sigma\bar{D}_k$	Area 60	Area 80
Cannon	0.147	0.038	0.318	0.072	0.512	0.123	0.733	0.183	48.6	4.3
Fairchild	0.128	0.026	0.271	0.051	0.433	0.077	0.616	0.103	263.6	26.9
Kelly	0.171	0.120	0.379	0.187	0.617	0.312	0.918	0.507	20.1	1.7
Macdill	0.157	0.047	0.344	0.077	0.557	0.125	0.807	0.181	77.9	4.4
McChord	0.149	0.070	0.329	0.133	0.548	0.211	0.806	0.306	36.6	1.5
Myrtle Beach	0.159	0.033	0.345	0.071	0.559	0.117	0.804	0.172	165.2	9.3
Randolph	0.173	0.034	0.374	0.069	0.608	0.101	0.885	0.132	47.5	2.3
Avg. D(k)	0.155	0.053	0.337	0.094	0.548	0.152	0.796	0.226	94.2	7.2
σAvg.	0.015	0.033	0.037	0.048	0.061	0.082	0.100	0.139	88.6	9.1
$\sigma\bar{D}_k$/Avg.	0.28		0.39		0.41		0.44			

Table III. Percentage changes in enclosed areas for 1 dB contour value changes at LDN 60, 65, 70, 75, 80, and 85 dB.

Base	LDN Contour Value (dB)					
	60	65	70	75	80	85
Cannon	14.1	12.2	11.6	12.3	16.2	12.5
Fairchild	8.5	11.0	17.6	11.4	11.6	13.6
Kelly	14.2	14.6	10.4	14.3	13.3	50.0
Macdill	20.8	15.6	11.9	13.2	18.9	20.0
McChord	13.0	15.6	18.2	15.2	25.0	14.3
Myrtle Beach	14.1	20.3	14.7	13.0	12.0	17.5
Randolph	16.7	14.4	16.2	20.5	15.0	12.5
Avg.	14.5	14.8	14.4	14.3	16.0	20.0
σ	3.7	3.0	3.1	3.0	4.7	13.5
σ/Avg.	0.26	0.20	0.22	0.21	0.29	0.67

characterization would be obtained. However, such a procedure would be somewhat clumsy to use compared to one based on contour value. Results similar to those shown in Table III would be obtained for other values of contour shift.

The results presented in Tables II and III suggest that the single values D(K) from Table II are a good representation of the fractional area change caused by a given change in contour value. These results may be easily compared to the proposed model for screening represented by Eq. (7) as shown in Fig. 1.

Since Eq. (7) is supposed to describe the percentage area change for fixed contour value, the agreement shown in Fig. 1 is excellent. In effect, Fig. 1 indicates that a change in contour value at a fixed point due to operational changes is very nearly the same as is caused by a contour value change with operations fixed. In fact, for changes in contour value from 1 to 5 dB, Eq. (7) and the results of NOISEMAP runs are within 1 standard deviation of each other.

The results for percentage change in enclosed area caused by a constant fractional change in operations for all aircraft at a base are shown in Fig. 2. The changes predicted by Eq. (10) are also shown for comparison. The figure indicates that for uniform changes in operations of less that 25%, Eq. (10) provides an adequate prediction for the change in enclosed area.

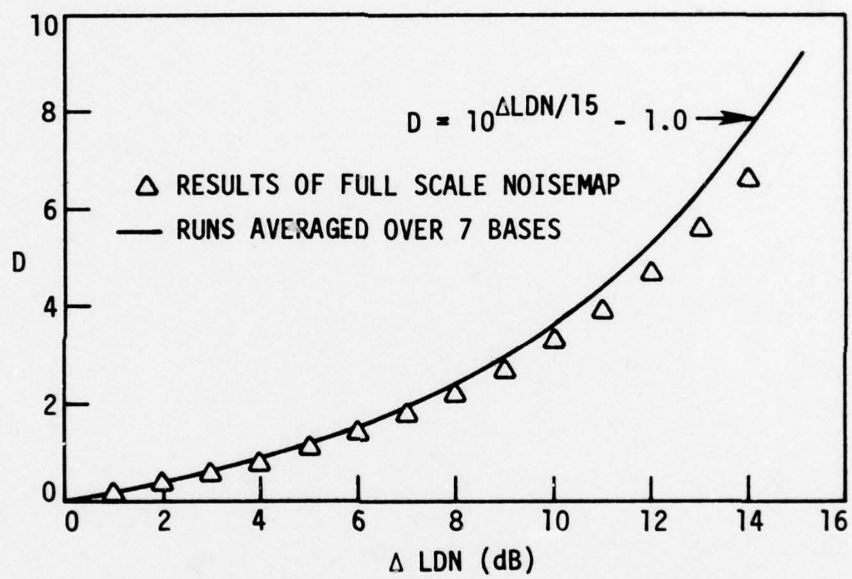

Fig. 1. Relationship between enclosed area change and change in contour value.

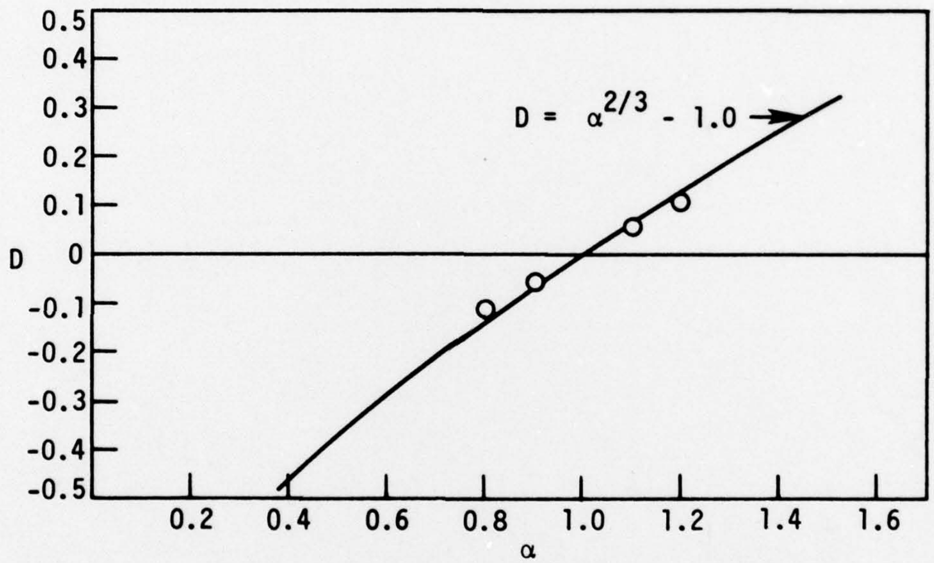

Fig. 2. Enclosed area change as a function of fractional change in operations.

CONCLUSION

The results of the work discussed in this paper may be summarized as follows:

1. An equation of the form LDN = B - 15 log (A) appears to be an adequate model for military air bases with B being a constant for a given base and set of operations.
2. Equations (7) and (10) are adequate for predicting change in enclosed area due to contour value change or operations change, respectively.
3. The change in enclosed area due to a change in operations which causes the contour value at a point to change is equivalent to the change in enclosed area caused by an equal contour value change with operations fixed.

The results suggest that a quantitative screening procedure based on change in area enclosed by a given contour is feasible. Such a procedure is also capable of estimating the impact of changes in base operations on the noise environment near a base.

ACKNOWLEDGMENT

This research was sponsored by the Engineering Research Institute of Iowa State University through a grant (Grant No. AFOSR 77-3308) from the Air Force Office of Scientific Research, Air Force Systems Command, USAF. The United States Government is authorized to reproduce and distribute reprints for Governmental purposes notwithstanding any copyright notation hereon.

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